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Radio Condenser Company.

Superheterodyne, tuning condensers, 1930

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SUPERHETERODYNE
Tuning Condensers

▼

Laboratory of the
RADIO CONDENSER COMPANY
E. D. KOEPPING, *Chief Engineer*

▼

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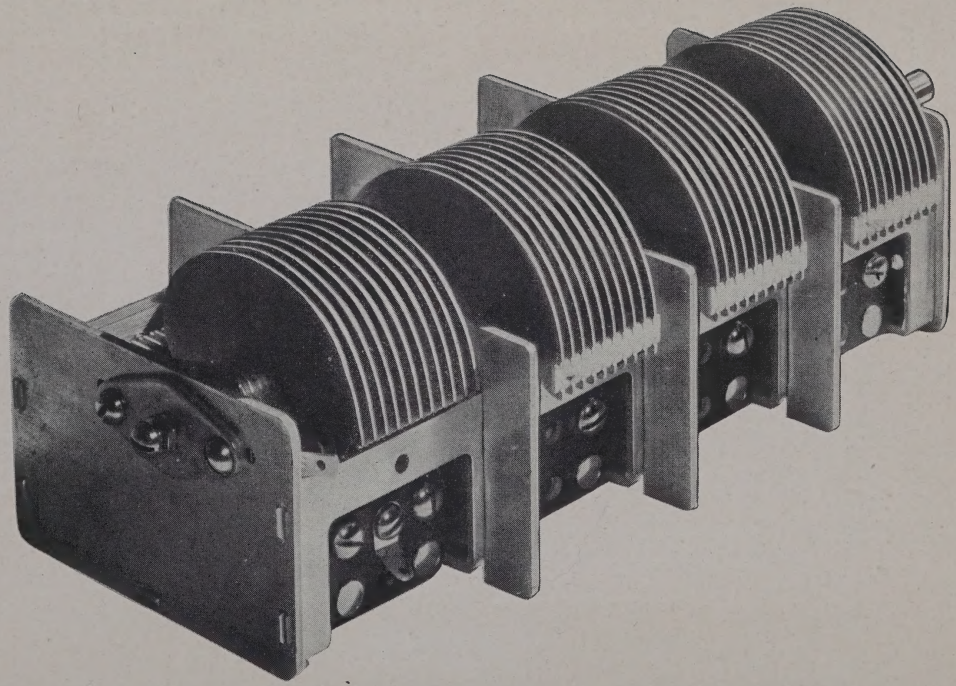

MODEL 410 SUPERHETERODYNE CONDENSER

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SUPERHETERODYNE TUNING CONDENSERS

GENERAL

The principle of the "Superheterodyne" or double detection (demodulator) system of radio reception is the underlying one of the heterodyne. This principle was discovered by Reginald A. Fessenden and patented by him. (U. S. Pat. 1,050,728 Jan. 14, 1913).

In practice the received signal frequency is mixed with a second frequency generated by a local oscillator to produce a third frequency which has a period equal to the difference between the first two frequencies. Fessenden made the period of the difference, or resultant, frequency very small so that it would produce an audible tone.

Later E. H. Armstrong (U. S. Pat. 1,347,885 June 8, 1920) made the resultant frequency high enough to be inaudible, in fact radio frequency, and amplified this frequency. This is the system which has been given the name "Superheterodyne." The reason for the invention was, primarily, the difficulty in satisfactorily amplifying the higher radio frequencies. By means of the heterodyne principle he created a third frequency of very much longer wave length than the signal, which he could then readily amplify in the usual manner successfully.

The system then was as shown in Fig. 1.

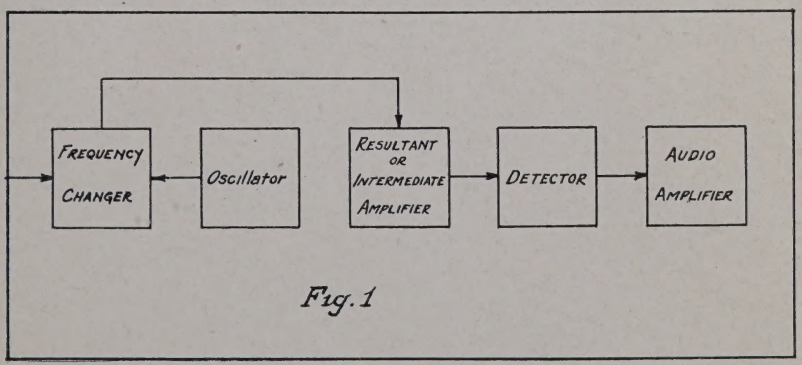

Fig. 1

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This was hardly a satisfactory system for broadcast reception in the United States for many reasons, chief among which were the many repeat points at which a single station could be heard and because the great number of stations operating caused a great cacophony instead of music.

Since this time a great deal of research has been carried on to preserve the obvious merits of the system and eliminate the features detrimental to its use in the hands of the public as a broadcast receiver.

Koepping (1924) and later others, raised the intermediate, or resultant, frequency amplifier to a value so chosen in relation to the broadcast spectrum that reception of a given station at more than one point was made entirely impossible. At the time this reduced the possible gain of the intermediate amplifier very materially but the receiver was far superior in general satisfaction.

All these early designs had two controls, which was one less than the t. r. f. receivers of the day.

The next three steps in the art were:

(1) Insertion of the tuned signal frequency amplifier ahead of the frequency changer.
(2) Reduction to single control.
(3) Use of screen grid tubes.

The screen grid tube permits good gain to be obtained at signal frequencies and as an intermediate amplifier even at comparatively high frequencies (500-505 Kilocycles) permits gains on the order of 60 to 80 per stage to be realized. These gains are of the same order of magnitude as those obtained at lower frequencies when the selectivity of the lower frequency system approximates that of the higher.

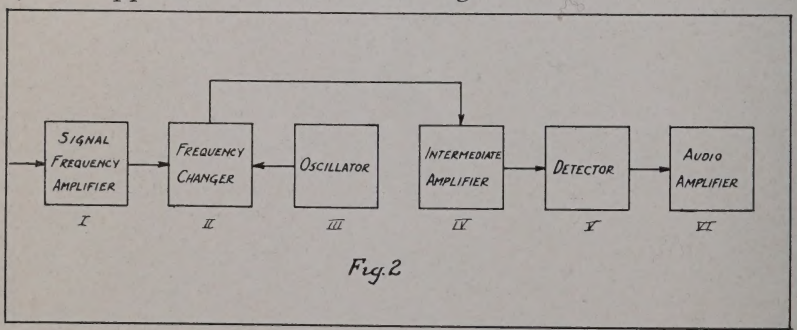

Fig. 2

SINGLE CONTROL PROBLEM

The final problem then is the one of single control for the system which now has the form shown in Fig. 2. Single control for superheterodynes of the older types was probably first proposed by J. L. McLaughlin (Q. S. T. Nov. 1924) who used a carefully chosen inductance value and a trimming inductance in series for the purpose. The condensers were to be identical in capacity and were geared to operate from a single control.

In the system of Fig. 2 the variably tuned components are the r. f. signal frequency amplifier (1), the frequency changer (2) and the oscillator (3). (1) and (2) are tuned to the same frequency and present no special problem. (3) is tuned to a different frequency and the ganging of this variably tuned circuit with (1) and (2) is the major problem under discussion as the satisfactory operation of the receiver depends upon how accurately it is done.

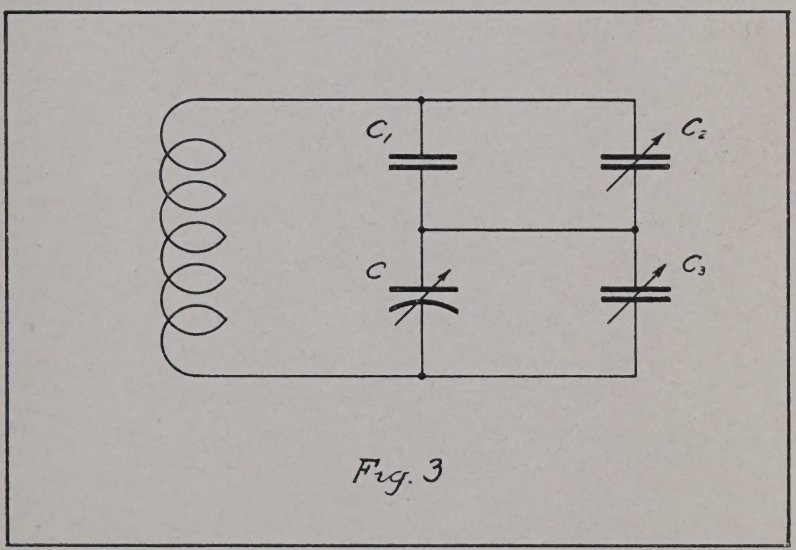

Fig. 3

For an example let us assume that the Intermediate Amplifier (4) is to operate at 175 Kilocycles. It will be tuned to this frequency and the function of the Oscillator is to generate current of such frequency that when it beats with the signal frequency the resulting beat frequency will be 175 Kilocycles.

It is at once apparent that the characteristics of the oscillator circuit differ entirely from those of the r. f. amplifier (1) and the frequency changer (2). If the oscillator is worked so that it is 175 KC higher in frequency than the r. f. amplifier its spectrum will be from 750 to 1700 Kilocycles, if it is worked at frequencies below the r. f. amplifier by 175 Kilocycles its spectrum will be from 350 to 1300 Kilocycles; while if worked partly at higher frequencies than the r. f. amplifier and partly at lower its spectrum would be 750 to 1300 Kilocycles. Of these combinations, only one is practical and economical for single control design and that is the one operating throughout the spectrum at frequencies 175 Kilocycles higher than the r. f. amplifier.

Inasmuch as intermediate frequencies can be anything from 30 Kilocycles up to 500 Kilocycles and the r. f. amplifier can have almost any imaginable frequency distribution it is obvious that the oscillator circuit could have innumerable characteristics, every one of which would require a slightly different oscillator condenser plate shape.

Fortunately these numberless variations in the r. f. tuning curve accomplish nothing of vital importance and one of them representing an average can be chosen for the purpose of designing an oscillator condenser to be ganged with the r. f. tuning condensers. A procedure such as this will be necessary unless the receiver designer wishes to pay the cost of individual dies and fixtures necessary to produce an oscillator condenser plate shape to meet his own choice of conditions. This is wholly unnecessary. Of course, the designer can use the standard plate shape of the r. f. tuning condensers and by series parallel padding achieve a characteristic for the oscillator condenser which is usable. The scheme is shown in Fig. 3 where C_1 is a capacity at least twice the value of C and C_2, C_3 are the usual trimmer condensers. The system is adjusted to the proper capacity value at the angle of rotation of highest signal frequency by means of C_3 and at angle of lowest signal frequency by means of C_2. Of course other points for balancing may be chosen at will, but however it is done some portion of the range will vary from the required value of capacity enough to considerably diminish the amplification. We have found departures from the required capacity as great as 12

mmfd when this system is used. Variations from the required capacity amounting to even 6 mmfd seriously affect the sensitivity of the receiver.

DEVELOPMENT OF THE OSCILLATOR CONDENSER PLATE SHAPE

Our problem has been that of designing an oscillator condenser in such a way that when used with an r. f. system of known characteristics it is capable of maintaining accurate tracking of the oscillator system at a frequency 175 Kilocycles higher than the r. f. system at the same angle of rotation.

When the characteristics of the r. f. circuit are known and its tuning curve has been plotted as θ against frequency, as for example Fig. 4, and the intermediate frequency has been chosen the frequency spectrum necessary for the oscillator will be known. In this case the spectrum of the oscillator will be from 1675 to 725 Kilocycles.

In order to be certain that the tracking of the oscillator may not be disturbed by variations in the lumped minimum capacity which may occur in various designs it will be necessary to design the oscillator condenser so that some capacity will have to be added by means of a trimmer condenser to make the sum of the lumped stray capacities and that added by the trimmer equal to a previously assumed value. In our design this value is 50 mmfd. This means that some capacity will have to be added by the trimmer, probably about 15 mmfd.

The inductance value for the oscillator circuit is then chosen and should be a value which will allow the necessary spectrum to be covered with a maximum capacity which is not unduly large. We have found 143.6 micro henries to be a suitable value.

From this data the necessary capacity values for the oscillator condenser at intermediate angles can be calculated. When these values have been ascertained and knowing the capacity values of the r. f. condenser at various angles of rotation, the radii required to give the desired capacity curve to the oscillator condenser can be calculated from the expression:

$$r_0 = \frac{r \dfrac{Co}{n}}{\dfrac{Cs}{n}}$$

Where,

Cs=capacity of r. f. condenser at θ

C_0—capacity of oscillator condenser at corresponding θ

r —radius of r. f. condenser plate at corresponding θ

r_0 —radius of oscillator condenser plate at θ

n —pairs of active surfaces in r. f. condenser unit.

The expression, of course, is capable of being applied to the solution of any required polar curve and is not limited to this particular problem.

The solution of the problem under discussion is exemplified in the graph Fig. 5. This shows the capacity curve of the oscillator condenser per se with its trimmer in the normal minimum position. This is not the capacity curve this unit has in actual use because when used the minimum is raised to 50 mmfd at 12 divisions by the lumped stray capacities of the receiver and by means of the trimmer. The graph of Fig. 5 should be considered in relation to that of Fig. 6. These two graphs show what the capacities of the r. f. condenser and the oscillator condenser should be when measured apart from the circuit at various angles of rotation. This would be done in making the original calibration of the gang during manufacture and probably also by the receiving inspection departments of receiver manufacturers.

This oscillator condenser is designed to be used with an oscillator coil secondary having an inductance 143.6 micro henries. When the minimum capacity of the circuit is set to the pre-determined value of 50 mmfd the proper frequency distribution of the oscillator spectrum is that shown in the graph Fig. 7.

VERIFICATION OF DESIGN

The receiver designer has two distinct problems apart from the design of his intermediate frequency transformers. The first is to carefully check his r. f. amplifier and make sure that it follows the graph of Fig. 4 very closely from one end of the spectrum to the other.

The second is to check the oscillator circuit and be certain that it follows the graph of Fig. 7 very closely throughout the spectrum.

Both of these measurements should be made on the final model with all vital parts in their proper place. The intermediate amplifier should then be adjusted and the peak brought to 175 Kilocycles.

A final check of the tracking of the r. f. and oscillator circuits should now be made. This can be done in the following manner: Attach a small 10 mmfd carefully calibrated variable condenser in parallel with the oscillator condenser. Supply a modulated signal of known frequency by a standard signal generator in the usual manner.

Turn the dial to the point where 1500 Kilocycles is the resonant frequency of the r. f. amplifier (equivalent to 12 divisions on graph Fig. 4) and back off the trimmer of the oscillator condenser until the capacity added by the small variable test condenser has been allowed for, and gain is maximum. The plates of the test variable condenser should be at an intermediate point such as 90 degrees when making this adjustment so that capacity can either be added or subtracted from the circuit by the test condenser.

Readings should now be taken at numerous points from 1500 Kilocycles to 550 Kilocycles and the gain brought to maximum in each instance by means of the test variable condenser. The variation from the initial setting should be noted and correction made to the oscillator condenser by means of the slotted plates. The variations, in proper designs, will never be greater than can readily be corrected for by the slotted plates. Adjustment of the test variable condenser will have to be made with a long insulator. The final point should be observed and checked with the fingers away from the adjusting device of the test condenser.

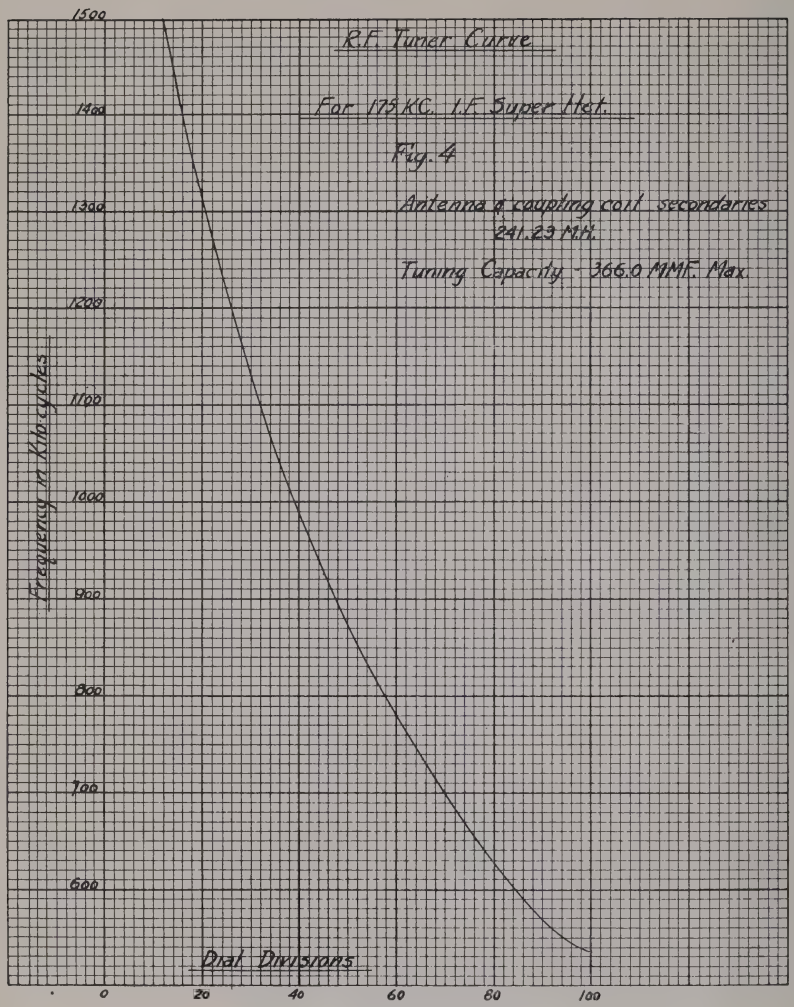
R.F. Tuner Curve
For 175 KC. I.F. Super Het.
Fig. 4
Antenna & coupling coil secondaries
241.23 M.H.
Tuning Capacity - 366.0 MMF. Max.
Frequency in Kilocycles
1500
1400
1300
1200
1100
1000
900
800
700
600
Dial Divisions
0
20
40
60
80
100

FIG. 4

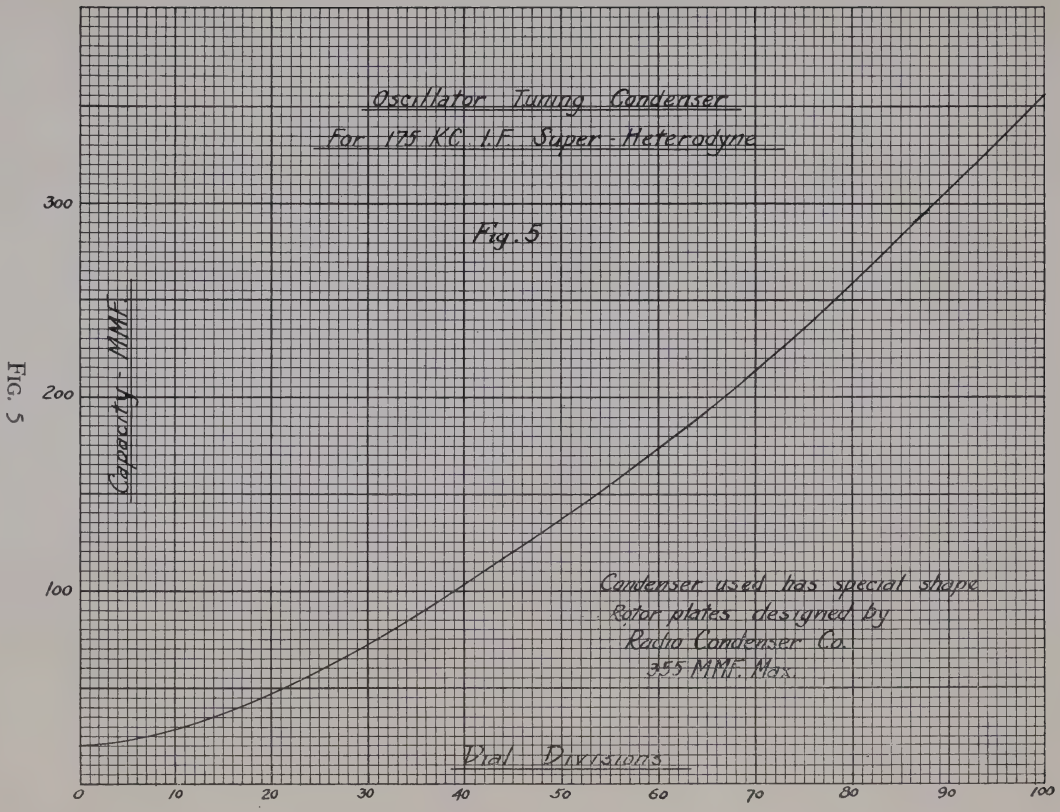
Oscillator Tuning Condenser
For 175 KC. I.F. Super-Heterodyne
Fig. 5
Capacity - MMF
300
200
100
Condenser used has special shape
Rotor plates designed by
Radio Condenser Co.
355 MMF. Max.
Dial Divisions
0
10
20
30
40
50
60
70
80
90
100

FIG. 5

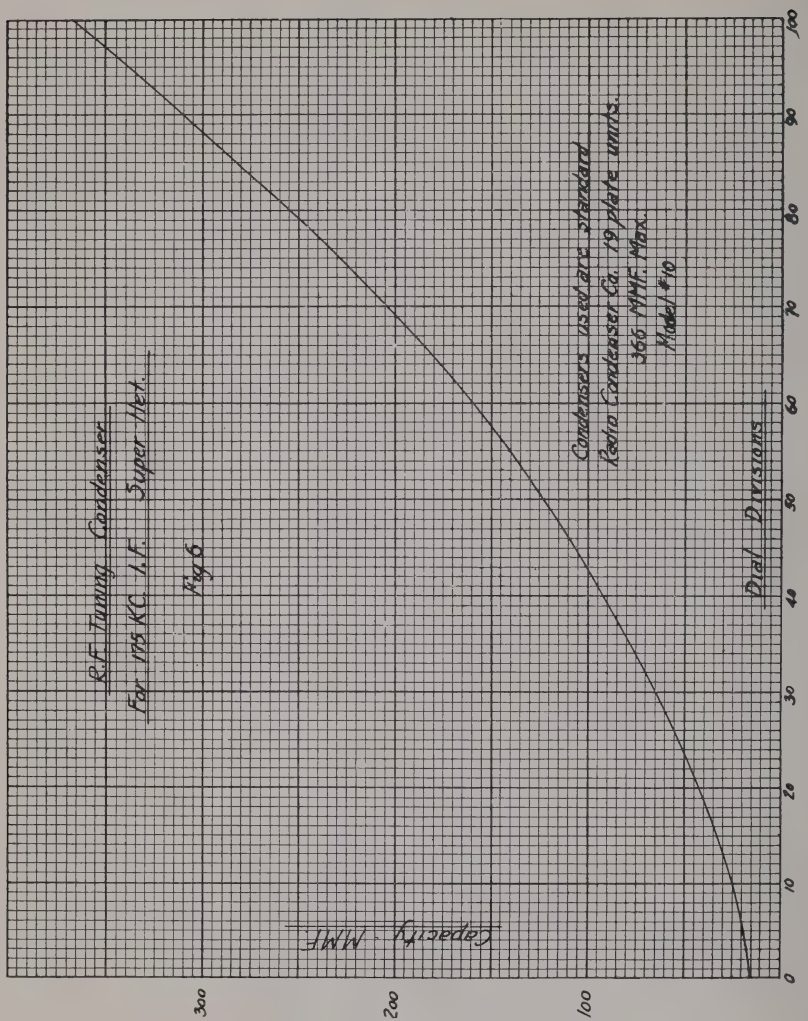
R.F. Tuning Condenser
For 175 KC. I.F. Super Het.
Fig 6
Condensers used are Standard
Radio Condenser Co. 19 plate units.
365 MMF. Max.
Model #10
Capacity - MMF
Dial Divisions
300
200
100
0
10
20
30
40
50
60
70
80
90
100

FIG. 6

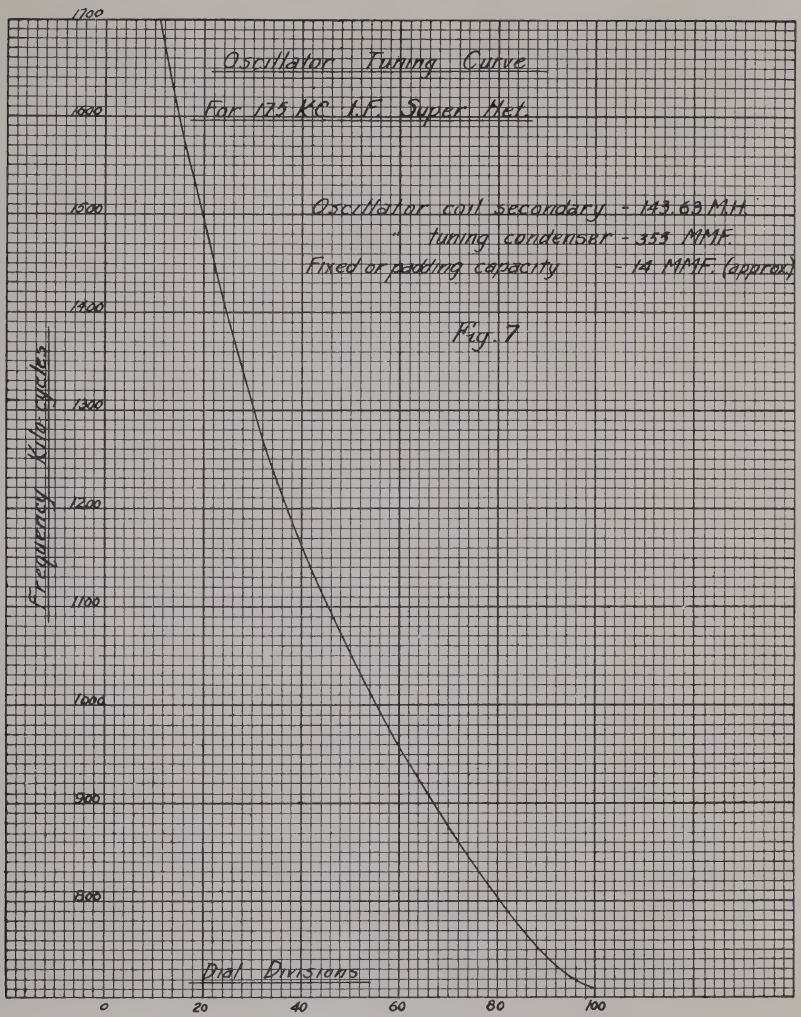
Oscillator Tuning Curve
For 175 KC I.F. Super Het.
Oscillator coil secondary - 143.63 MH.
tuning condenser - 355 MMF.
Fixed or padding capacity - 14 MMF. (approx.)
Fig. 7
Frequency Kilocycles
1700
1600
1500
1400
1300
1200
1100
1000
900
800
Dial Divisions
0
20
40
60
80
100

FIG. 7

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